Alignment and Pseudospin Symmetry

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The concept of pseudospin symmetry has proved useful in describing the "normal parity" states of nuclei. In this scheme the total angular momentum, j, of a particle is unchanged, but is decomposed into pseudo-orbital, $\tilde{l}$, and pseudo-(intrinsic)spin, $\tilde{s}$, components. Perhaps the most striking success of the pseudospin scheme is the explanation of closely spaced doublets with quantum numbers, $\Omega = \tilde{\Lambda}\pm1/2$, that occur in nuclear energy levels. It is the very weak pseudo spin-orbit coupling that provides the natural explanation for these doublets. The alignment of pseudospin (due to the weak spin-orbit interaction) has been invoked as a possible explanation for some of the "identical" bands observed in superdeformed (SD) nuclei.

In the pseudospin scheme the state [301]1/2 becomes $[\tilde{2}\tilde{0}\tilde{0}]1/2$ and the alignment, which would be zero in the asymptotic limit, becomes $\pm1/2$ in the pseudospin limit. This proton orbital was used as the explanation for identical SD bands in ^{152}Dy and ^{151}Tb. These bands have the same transition energies, requiring exactly half-integer alignment, which the $[\tilde{2}\tilde{0}\tilde{0}]1/2$ orbital can provide. For the $\tilde{\Lambda} > 0$ doublets, the Coriolis force can align $\tilde{\Sigma}$ parallel or anti-parallel with the rotation axis, resulting, when complete, in two signature-degenerate bands the lower of which has alignment +1/2, and the upper -1/2. These bands can also give rise to identical bands between odd-mass and even-even nuclei, and one such case has recently been suggested for bands in ^{191}Au and ^{192}Hg. In this case the orbitals proposed were $[\tilde{4}\tilde{3}\tilde{1}]1/2,3/2$. If such $\tilde{\Sigma}$ alignment occurs in $\tilde{\Lambda}$=1 bands, there should be examples in the normally deformed nuclei, and the present work is a search for these.

The only good set of data we found was on the neutron orbitals, $[\tilde{4}\tilde{1}\tilde{1}]1/2,3/2$. This pair of orbitals is lowest-lying in the W and Os nuclei having neutron numbers (N): 109, 111, and 113. The mixing, if complete, should produce alignments $\pm1/2$ in the two bands, or alignment exactly one relative to each other and this would result in equal transition energies in the two bands, but connecting states that are $1\hbar$ higher in the lower band. The data for N=111 show $1\hbar$ relative alignment rather convincingly, as expected. The N=109 nuclei also have average alignments around $1\hbar$; however, the values expected would be about 30% smaller. The bands in nuclei with N=113 are too far apart in energy to align $\tilde{\Sigma}$ completely, but are in agreement with calculations and should reach full $\tilde{\Sigma}$ alignment at higher spins. The agreement seems satisfactory, suggesting that the expected $\tilde{\Sigma}$ alignment does occur in these nuclei.

The next step is to look at the mean alignment of the two bands in a nucleus relative to an adjacent even-even nucleus, which would be zero if the alignments in the bands were $\pm1/2$ and nothing else was happening. This would be necessary in order to explain the ^{191}Au identical band case. This mean alignment relative to the lower-mass even-even isotope averages about $+0.4\hbar$ for all the cases, which is too large to produce identical bands. This extra alignment could be due either to pairing (blocking) effects or some alignment of $\tilde{\Lambda}$. However, both of these should be smaller in SD nuclei due to the weaker pairing at higher spins and the wider spacing of the $\tilde{\Lambda}$ states at larger deformation. In conclusion, this process can provide a plausible explanation for the identical bands in ^{191}Au and ^{192}Hg, although with just this one case an accidental half-integer alignment cannot be ruled out.

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